Evaluation of goat populations in tropical and subtropical environments

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Summary

GOATS IN *the tropics are kept under varying ecological conditions and greatly differing husbandry systems. Although managed in many rational ways, performance is highly influenced by a large number of environmental factors. Production objectives vary according to ecological conditions and the production system.*

Improved goat productivity is possible through better management and controlled breeding. Logical decisions on improvement strategies require accurate performance data and adequate information on the impact of systematic factors. Various methods of breed documentation or breed evaluation can be applied. While breed documentation is sufficient for better management and selective improvement, meaningful performance comparisons require simultaneous breed evaluation. Productivity characteristics are most important but parameters describing specific performance abilities also need consideration.

Field and on-station tests are complementary, although the field tests are the most meaningful. The problems posed by the large number of influencing factors and covariates can be solved by choosing the correct samples and ensuring a systematic implementation of test schemes. Within-flock comparisons require large flocks and are less feasible than grouped flock comparisons for production systems with a small flock size.

Introduction

Goats are widely distributed throughout the world, but are particularly associated with less favourable environments. Adaptive features such as feeding behaviour, efficient feed utilisation and, in part, disease tolerance enable goats to thrive on natural resources left untouched by other domestic ruminants. In marginal environments it is the only domestic species able to survive. Its biological features include an efficient reproductive system and a small body.

These characteristics allow an easy adjustment of flock size to match the available resources, facilitate the integration of goats into small-scale production systems (low capital, low risk) and enable flexible production. Goats can serve two different functions in a development economy:

- provide food and raw materials by utilising ecologically marginal areas, and
- increase family income and the financial stability of smallholder enterprises by utilising limited economic and natural resources.

If goats are to serve as a source of both food and cash, their productivity must be increased through improved husbandry and breeding strategies.

This paper describes the role of goats in farming systems in tropical and subtropical regions, outlines methods used to evaluate their performance and provides information on how to conduct performance tests in the field.

The role of goats in farming systems

Production system and goat husbandry

Goats form an integral, but rarely dominant, component of most farming systems in the tropics and subtropics (Winrock International, 1983). Although their importance is more pronounced at either end of the ecological gradient (arid to semi-arid and in the humid zones) than in more favourable environments, goats still play a part in almost every farming system (Table 1).

Table 1. *Goat management in tropical zones and production systems.*

Ecological Zone	Agricultural System	Production system	Animal species	Management practice		Feed resources	Flock size	Location (examples)
				Day	Night			
Arid to semi-arid	Pure Livestock	Transhumant pastoralism	Goats, sheep cattle	Free-range herding	Open camp	Predominantly browse	30–80	Mali, Sudan
		Semi-sedentary pastoralism	Cattle, goats sheep	Flock herding	Penned	Browse and grass	10–100	Kenya (Maasai)
Semi-arid	Crop–livestock	Agropastoralism	Cattle, goats	*Dry season* free roaming	Penned or tied	*Dry season* crop residues, fallow, browse	5–40	Mali, northern Nigeria
				*Crop season*Herding		*Crop season*grass and browse		
Sub-humid	Crop-livestock	Small-scale mixed farms	Cattle, sheep goats	*Dry season*Herding	Penned or tied	Dry season crop residues crop fallow	2–10	Kenya, Mali, Southern Nigeria
				Crop season Tethering		Crop season limited natural vegetation	5–20	Malaysia
Humid	Crop-based	Large-scale plantations	Sheep (West Africa)	Paddocking	Penned	Natural undergrowth	40–400	Malaysia

			Goats (Asia)	Herding		(grasses, forbs, ferns)		
		Small-scale cropping	Goats	Housed	Housed	Grass Crop residues	2–20	Malaysia southeast Nigeria

Ecological conditions, feed resources and interactions with the cropping subsystem determine the goat management system. With only few exceptions, goats are allowed to range free in the arid zones, while in the subhumid and humid zones they are kept under more controlled conditions. During the day, these may vary from free range to tethering or stall feeding; at night, goats are kept in open camps or confined (Sumberg and Mack, 1985; Wilson et al, 1983). Flock sizes decline as ecological conditions improve and the importance of integrated crop-cattle production increases.

Large-scale goat production is widespread in areas with a Mediterranean-type climate. Under tropical conditions it is limited to perennial crop systems such as the rubber plantations in Southeast Asia and cocoa plantations in West Africa (Peters et al, 1981; Peters and Horst, 1981). Even in pastoral areas, flocks of more than 100 goats are rare, but flocks of 20 to 30 are very common. In crop-livestock systems, flock size is negatively correlated to the importance of cropping, with each flock seldom having more than 20 goats (King et al, 1984; Wilson, 1983).

Management objectives

In the transhumant systems, goats are kept mainly for milk. Meat is a product of almost every system, while fibre production is confined to systems in the arid and highland zones (Table 2). Flock structures appear to be very similar in all ecological zones and production systems, regardless of the primary objective of keeping goats. Wilson (1983) reported that, in general, flocks have about 75% total females or about 50% breeding females.

Table 2. *Output goals of tropical goat production.*

Ecological zone	Production system	Output	Region
Arid	Transhumance (horizontal)	Milk, meat, hair	North Africa, Near East, India
	Sedentary Ranging	Meat (milk, fibre)	Latin America
	Ranching	Fibre (meat)	USA, southern Africa, Turkey
Semi-arid	Semi-sedentary pastoralism	Meat	East Africa
	Agropastoralism	Meat	West and southern Africa
Subhumid	Mixed farming	Meat	Africa, Latin America, South Asia
Humid	Lowland mixed Farming	Meat	Southeast Asia
	Upland perennial Cropping	Meat	Southeast Asia, West Africa
Highland	Transhumance (vertical)	Fibre, meat, milk	Northern India, Turkey
	Sedentary ranging	Fibre, meat	Lesotho
	Mixed farming	Meat	Ethiopia

Source: Based on Peters and Horst (1981).

Adaptability to ecological conditions

Goats are able to produce under greatly varying and frequently unfavourable environmental conditions. The most important adaptive features enabling them to adjust to the environment in which they are reared are feeding behaviour, body size and fleece structure (Table 3).

Table 3. *Environmental constraints and corresponding adaptations in goats reared under tropical conditions.*

Ecological zone	Environmental constraint	Type of adaptation zone
Arid	Seasonal availability of Vegetation Predominance of bush and shrub plants Lack of surface water High radiation, large fluctuations in diurnal temperature	Ability to survive on sparce vegetation Preference for browse, selective feeding, good rangeability Intake of succulents Larger body size and insulating coat
Humid	Fast-maturing grasses (high rate of lignification) High temperature and high humidity Tsetse infestation	Low absolute Requirements Small body size
Mountainous	Large variations in seasonal temperature	Development of trypano-tolerant breeds Fine woolly Undercoat

Goats are not only able to select a high quality diet and to compensate for their limited rumination capacity; they also consume more plant species than other domestic livestock (Demment and van Soest, 1983). Their unique feeding behaviour allows them to overcome the effects of limited feed availability in dry areas and select palatable parts of plants with a high crude fibre content (e.g. fast-growing grasses in the humid zone).

Another important adaptation of goats to ecological conditions is their variable body size. Goats inhabiting hot, humid environments have small bodies (dwarfs), while those living in dry environments or in areas with a wide diurnal temperature range usually have larger bodies (Horst, 1984). The combined effect of appropriate body size and feeding behaviour enables goats to withstand environmental stress and may be one reason for the relatively high disease tolerance attributed to goats under unfavourable environmental conditions.

Fleece structure shows a remarkable association with environmental conditions. In the semi-arid to humid zones, short coats of coarse fibre enable goats to withstand high rates of radiation or humidity. Goats inhabiting the arid zones have long-haired, coarse-fibre fleeces to protect against heat during the day and cold at night. In the mountainous areas of central Asia, goats have a top coat of long coarse fibres and a seasonal undercoat of short, fine fibres to protect against extreme cold. Angora or mohair goats have long, white and wavy fleeces and live in mid-altitude (Turkey) and dry, high-altitude areas (Lesotho).

In summary, ecological conditions, available feed resources and management systems may affect the productive adaptability of goat populations in specific environments. These factors must be regarded as covariates and must be established when testing goat performance.

Performance evaluation

Objectives

The performance abilities of goat breeds must be thoroughly understood before attempts are made to increase the productivity of these animals. The major objectives of evaluating breed performance are to:

- determine performance levels and specific adaptive abilities,
- determine the environmental and genetic factors that cause variability in breed performance
- compare the performances of different pure or crossbred breeds in the same environment.

Methods

Goat performance can be evaluated by focusing on a single breed, or by comparing several pure or crossbred breeds under identical environmental conditions (Table 4). The first method allows the documentation of absolute performance by a given breed with particular physiological and genetic characteristics in a given environment. This information is useful to design management and breeding strategies for within-breed improvement through better husbandry and selective breeding. The second method enables a simultaneous evaluation of performance of different goat populations in a given environment, through the comparision of the relative merits of all the genotypes involved. Breed-type evaluation is particularly important to the success of crossbreeding programmes.

Table 4. *Methods used to assess breed performance.*

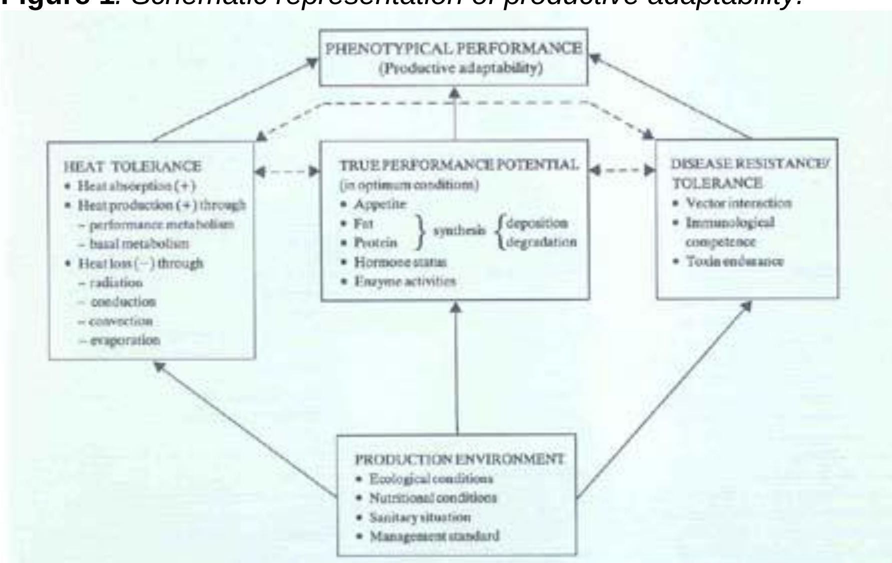
DOCUMENT Absolute performance of • specific production characteristics • morphological and physiological criteria Observations of • specific polymorphisms • single/major genes Advantage: Enables the preparation of standardised descriptions of particular breeds in different regions and countries. Applicability: Useful to determine within breed performance ability and variability, and husbandry and breeding strategies.
EVALUATE Relative performance • in identical environments • of same characteristic or criterion Advantages: Enables easier definition of performance characteristics; between-breed comparison is not confounded by different performance tests and environmental effects. Applicability: Necessary to identify more suitable breeds and useful genetic resources.

The choice of method depends on such factors as the production system and its objectives. In traditional subsistence systems, improved management is needed rather than introduction of new genes; thus the appropriate method is breed documentation. For more intensive systems, however, comparative breed performance studies are needed to identify the best genotype available.

Components of a performance test

Horst's (1983) concept of 'productive adaptability' implies that phenotypical performance is the result of an animal's true genetic performance ability plus its specific ability to cope with such environmental stresses as disease and heat (Figure 1). The interactions of these factors shape the productive performance of a given breed, and it is important that both be considered before decisions are made on improvement strategies.

Figure 1. *Schematic representation of productive adaptability.*



The characteristics which must be taken into account when evaluating goat performance can be divided into three groups: productivity, specific performance ability and specific adaptation ability.*Productivity* is an important indicator of the overall, economically relevant performance ability, but also gives a first impression of specific performance abilities and their variability (Table 5).

Table 5. *Productivity characteristics and measurements needed for calculations.*

Flock meat productivity (FMP)						
FMP = litter/year (parturition interval)	×	kids/litter (number weaned)	×	kids' viability to weaning (weaning weight)	×	kids' weaning weight (survival rate of doe)
Flock efficiency (FE) FE $= FMP/\text{doe weight}^{0.75}$ Flock performance productivity (FPP)[1] $FPP = FMP + \left(\frac{[\text{daily milked-out yield}] \times [\text{days of lactation}]}{9}\right)$ $= FMP + \left(\frac{\text{milk yield}}{9}\right)$ Flock performance efficiency (FPE) $FPE = FPP/\text{doe weight}^{0.75}$						

[1]Expressed in meat equivalents; 1 kg of meat = 9 kg of milk.

To understand the performance pattern for particular breed characteristics, and to provide the basis for genetic evaluation of each characteristic, detailed information about the *specific performance ability* of a breed is needed (Table 6). This group of characteristics includes fertility, lactation and growth, but also fibre yield and composition, skin structure and other related parameters.

Table 6. *Characteristics of specific performance ability and observations needed to assess them.*

Characteristic	Observation
Fertility	Age and weight at sexual maturity Oestrus cycle and pattern
doe fertility	Post-partum ovulation rate
	Fertilization rate
	Embryo survival
	Gestation period
buck fertility	Age and weight at sexual maturity
	Libido, non-return rate
	Semen quality
Lactation	Maternal and milking behaviour
	Milk yield
	Days in milk
	Persistency
	Milk composition
Growth	Tissue growth (prenatal, postnatal)
	Feed intake (appetite)
	Body composition
	Carcass quality (meat yield)
Fibre	Fibre yield (weight, yield)
	Fibre density
	Composition (primary, secondary fibre)
	Fibre diameter and structure
	Strength of fibre
	Elasticity
	Length
Skin	Surface area
	Thickness, uniformity
	Grain structure
	Elasticity

The usefulness of the criteria by which the *specific adaptation ability* of a genotype is judged is controversial (Horst, 1984). However, the between-breed differences of disease susceptibility and heat tolerance observed in sheep and cattle in tropical environments justify the inclusion of specific adaptation ability in performance evaluations, despite the uncertainty surrounding its mode of inheritance (Table 7).

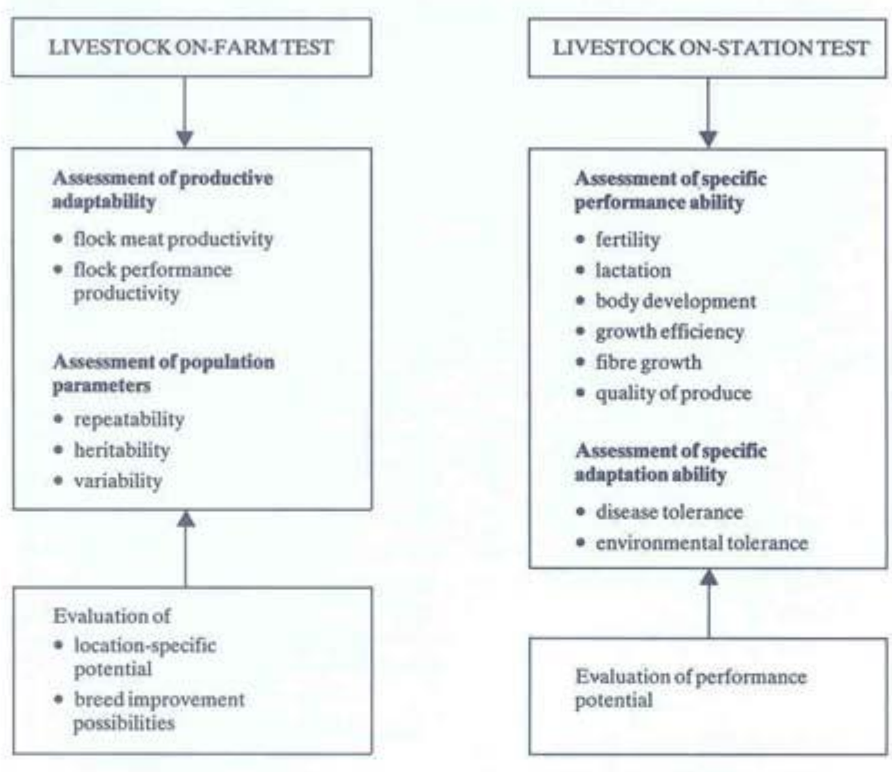
Table 7. *Characteristics of specific adaptation ability and observations needed to assess them.*

Characteristic	Observation
Disease tolerance	Packed cell volume Infection rate Parasite load Response to parasite inoculation Nutritional status (condition, weight changes) Polymorphism
Heat tolerance	Rectal temperature Respiration rate, pulse rate Evaporation rate Water intake (performance ability)
Water metabolism	Water loss Colon water resorption Kidney water resorption Body temperature development (performance ability)
Feed utilisation ability	Cell-wall digestion Phenolic-compound tolerance

Test location

An accurate assessment of productive adaptability can only be obtained if breed performance is assessed under normal living conditions. This is the reason for livestock on-farm tests (LOFTs), which are used to test large numbers of animals under actual producer conditions and allow a complete productivity assessment (Figure 2).

Figure 2. *Comparison of livestock on farm and on-station tests.*



Other elements of a performance test, the genetic performance ability of a given breed and its specific adaptations, need to be studied in the controlled environment of an experiment station (Figure 2). Livestock on-station tests (LOSTs) facilitate accurate data collection and allow animals to be tested under different levels of production intensity. The significance of the results will depend on the degree of standardisation of the station conditions and on how closely they imitate the actual production environment.

Livestock on-station tests are normally carried out with only a limited number of animals. They are complementary to the LOFTs in any performance evaluation, as both tests are needed to provide comprehensive data. LOFTS are undoubtedly the more important element, but their implementation is frequently hampered by a number of problems.

Problems encountered in LOFTs

In extensive goat production systems the main problems are mobility, an asynchronous production cycle and multiple outputs (Table 8), which can only be overcome by close monitoring of the flock. Access to flocks by the researcher depends largely on the cooperation of the owner, which can sometimes only be secured through direct incentives.

Table 8. *Problems encountered in livestock on farm performance tests (LOFTS).*

Problem	Issue	Solution
High mobility	Pastoral systems	Monitor flocks closely
Length of production cycle	Specific risks affecting one animal, one farmer	Use adequate sample Size
	Covariants affecting whole sample (e. g. season, disease)	Estimate correction factors if sample adequately distributed
Asynchronous production	Aseasonal breeding	Monitor different characteristics at regular intervals
Multiple output	Multi-purpose breeds	Incorporate different characteristics in performance recording
Negative attitude of owner	Hinders access to flock	Explain the purpose of the test and provide incentives
Ownership	Mixed ownership of flock	Involve owners in the test
Small flock size (< 2 animals)	Confounded farm and animal effects	Exclude single-animal
		flocks from sample
		Correct for farm effects
		Use grouped-flock comparisons
Single-buck flock	Confounded buck and flock effects	Interchange bucks between flocks
Management variability	Heterogeneous production conditions	Select a representative and sufficiently large sample
		Use within-flock comparisons
		Use grouped-flock comparisons

If the test covers more than one production cycle, proper identification of individual animals and accurate breeding histories of tested animals are necessary. Normally, such information is obtained from the owners, but difficulties may arise when flocks have mixed ownership.

In smallholder goat production systems, the average flock is larger than two does and thus is not a problem in performance testing. Single-buck flocks may pose a problem if buck performance were to be evaluated because the effects of individual flocks will have to be isolated from buck effects.

Lastly, the performance characteristics of goats are affected by a number of covariates, including seasonal influences, feed availability, climatic variations, disease stress and population size. To be able to estimate these covariates, and make the necessary adjustments, a data base built up over at least 2 years is required.

Implementation of field performance tests

Sample size

At any stage during breed evaluation studies the animals are exposed to a multitude of factors which affect their performance. The variability of these influences is especially high in field tests. ILCA's data from various ecological zones show that the coefficient of variation for the reproduction parameter of goats is about 35% and for growth 30% (Sumberg and Mack, 1985; Wilson and Durkin, 1983).

Large test samples are required if the significant between-breed differences in performance are to be correctly identified. For example, if we expect the difference between the true performance and the sample mean not to exceed 5%, and if the test of significance is carried out on a single breed (one-tailed test), a minimum sample size of approximately 800 animals is needed (Table 9).

Table 9. *Sample size in comparative breed evaluation: Number of replications required for a given probability of obtaining a significant result.*

True difference as % of mean	Coefficient of variation												
	4	6	8	10	12	15	20	25	30	35	40	45	50
5	9	19	33	50	72	112	198	310	446	607	792	1002	1238
	12	26	45	69	69	99	155	429	617	840	1097	1388	1714
10	3	6	9	13	19	29	50	78	112	152	198	251	310
	4	7	12	18	26	40	69	108	155	210	275	347	429
15	2	3	5	7	9	13	23	35	50	68	88	112	138
	3	4	6	9	12	18	32	49	69	94	122	155	191
20	2	2	3	4	6	8	13	20	29	39	50	64	78

	2	3	4	5	7	11	18	28	40	54	69	87	108
25	2	2	2	3	4	6	9	13	19	25	33	41	50
	2	2	3	4	5	7	12	18	26	35	45	57	69
30	2	2	2	3	3	4	7	10	13	18	23	29	35
	2	2	3	3	4	5	9	13	18	24	32	40	49

Upper figure: test of significance at the 5% level, probability 80% = one-tailed tests
Lower figure: test of significance at the 5% level, probability 90% = one-tailed tests

Source: Cochran and Cox (1957).

In addition, the sample must be adequately distributed over the different covariates in a given test area and must have a mating structure which makes it possible to estimate population parameters. For example, it must provide information on the number and distribution of bucks in flocks to avoid confounding buck-flock effects; the number of matings per buck to estimate heritability and genetic correlations using the half-sib covariance analysis; and it must include bucks that have been used for more than 1 year to avoid confounding buck-year effects.

Methods

The implementation of field performance tests requires considerable planning. First, a schedule for flock visits is necessary to cover the production cycle (birth, weights at different ages, weaning, mating). The data collected on individual goats are then entered onto prepared field data sheets and transferred to coding sheets. Further handling of the data involves a number of steps (Trail and Durkin, 1982):

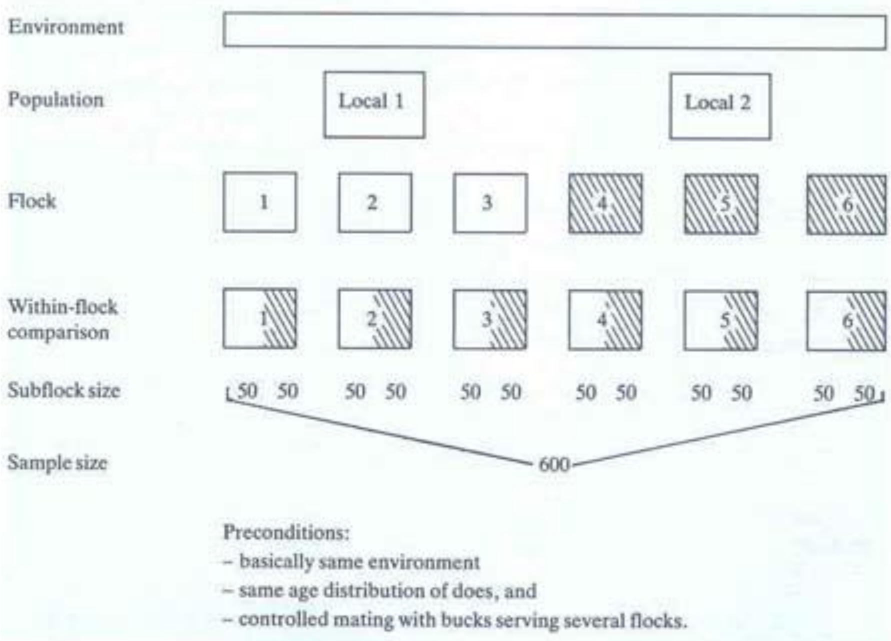
- enter data into a computer file;
- validate data and, if necessary, correct;
- calculate parameters (e.g. correction of weight to a given age);
- identify logical subclasses for environmental and other systematic effects;
- analyse data.

Both breed documentation and comparative breed evaluation are performed using this process. For a breed evaluation, however, it is also necessary to have an experimental plan which fits the respective conditions of the management system and flock size. Two such plans were designed by SABRAO (1981; Turner, 1982) - the within-flock comparison and the grouped-flock comparison.

Within-flock comparison

For a within-flock comparison of indigenous breeds, *at least* four flocks of 100 breeding does each are required, two flocks of a particular breed designated as LI and two of an L2 breed. The flocks are interchanged with an equal number of flocks comprising half L1 and L2 each. Figure 3 demonstrates within-flock comparison of six flocks from two local populations. The distribution of independent variables, such as environment and age of doe, should be similar for each flock. A certain degree of controlled mating per subherd facilitates the data recording process, and bucks should not serve in one herd only. Individual pedigrees are obtained only if individual coatings are recorded.

Figure 3. *Within flock comparison of goat populations.*



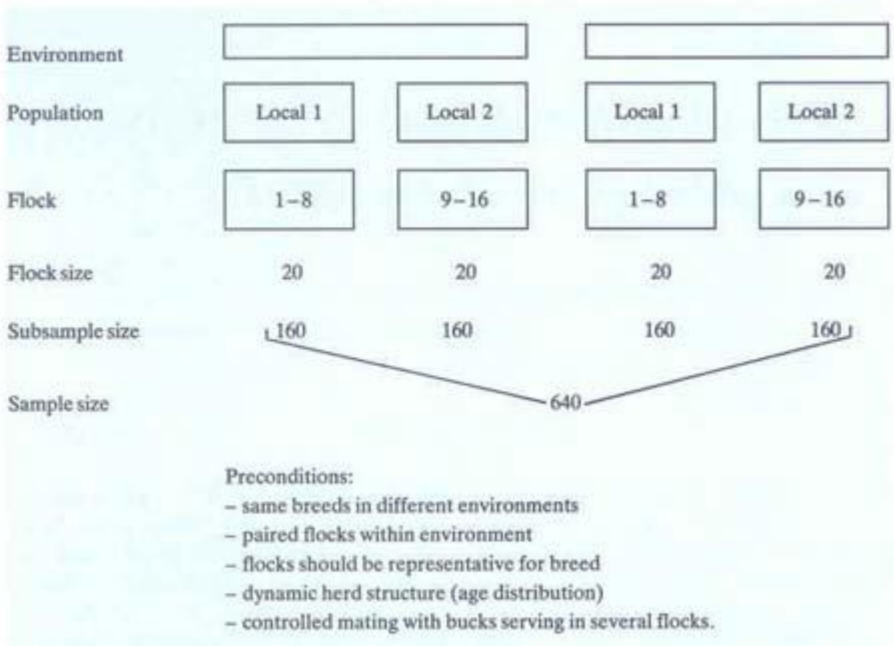
Goats in each subherd are identified by coloured ear tags or ear notches; newborn kids are marked accordingly. Three consecutive progenies must be observed before a complete set of data is obtained on one generation. This can take up to 4 years if kidding intervals are as long as 12 months; if goats give birth every 8 months, the observation period is much shorter.

Within-flock comparisons require large samples, and are therefore best carried out in pastoral and other range systems. The major drawback, however, is that animals must be moved in order to obtain composite flocks, and this seems feasible only under sedentary range or ranching management. Thus this method is less suitable for assessing goat performance than a grouped-flock comparison.

Grouped-flock comparison

This plan is carried out with a large number of paired flocks which may vary in size but are representative of a given breed in a given environment (Figure 4). An environment can include a whole agro-ecological zone, the production systems within an agro-ecological zone or villages within a production system. Controlled mating with bucks serving several flocks is a prerequisite, as well as a dynamic flock structure.

Figure 4. *Grouped-clock comparison of goat populations.*



There are other conditions that must be satisfied in group-flock comparisons: because of the large number of flocks studied in different environments, individual flocks must be properly identified, management practices must be controlled at least partially, and all covariates must be closely monitored. In smallholder systems where flocks may have five or fewer breeding does, about 120 flocks are required to obtain an adequate sample and ensure proper correction of covariates.

Grouped-flock comparisons are particularly suitable to compare the effects of crossbreeding which is usually done by mating exotic bucks with local does or through artificial insemination. Simultaneous mating of half the doe herd with local bucks then provides a sound basis for a performance comparison between the two genetic groups.

Conclusions

Evaluation of goat performance in the tropics must be approached systematically, but is expensive and requires considerable professional dedication. Unfortunately, at least one of these prerequisites is often lacking, and as a result few accurate data on goat performance are as yet available to introduce suitable improvement strategies.

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